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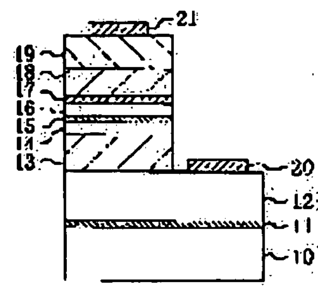
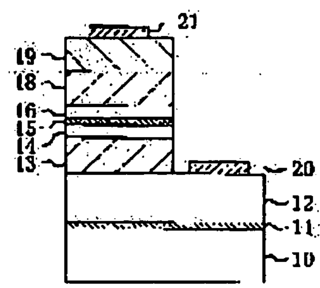
(54) MANUFACTURE OF SEMICONDUCTOR AND SEMICONDUCTOR DEVICE

(57)Abstract:
PROBLEM TO BE SOLVED: To form a p-n junction having a steep dopant profile in a gallium nitride semiconductor.
SOLUTION: On a sapphire substrate 10, an n-type GaN contact layer 12, an n-type $Al_{0.1}Ga_{0.9}N$ clad layer 13, a first GaN light guide layer 14, an $In_{0.20}Ga$. $_{0.80}N$ quantum well active layer 15, and a second GaN light guide layer 16 are successively formed. On the upper surface of the second light guide layer 16, an $Al_{0.1}Ga_{0.9}N$ diffusion suppressing layer 17 having a film thickness of 20 nm and doped with Mg as a p-type dopant and Si as an n-type dopant is formed and, on the upper surface of the layer 17, a p-type $A_{0.1}Ga_{0.9}N$ clad layer 18 is formed.

(a)



(b)



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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the semiconductor device using the manufacture approach of the GaN system III-V group compound semiconductor used for purple-blue color luminescence equipment, and this compound semiconductor.
[0002]
[Description of the Prior Art] In recent years, research and development of the semi-conductor luminescence equipment using the III-V group compound semiconductor of a gallium nitride (GaN) system which emits purple-blue colored light as the light source for a next-generation full color display are performed briskly. This semi-conductor luminescence equipment becomes important [that come to insert a barrier layer by p-n junction, and an impurity is not contained in this barrier layer] for quality improvement. That is, distribution of p mold dopant and n mold dopant needs to be steep.
[0003] since [moreover,] activation of p mold dopant is controlled by hydrogen passivation even if the compound semiconductor of a wideband gap like GaN dopes p mold dopant -- low -- it can be hard to obtain a p type semiconductor layer [****]. for this reason -- low -- in order to obtain a p type semiconductor layer [****], it is necessary to dope p mold dopant to high concentration, and to perform annealing treatment etc.
[0004] Hereafter, the control approach of the conventional p mold dopant is explained. Generally bis (cyclopentadienyl) magnesium (Cp2 Mg) is used for p mold dopant of GaN. however, crystal growth -- organic metal vapor growth (MOVPE) -- in using law, the problem that Mg which is p mold dopant is spread even in addition to a predetermined crystal is during the crystal at the time of growth ("Applied Physics Letters, Vol.55 (1989) pp.1017-1019"). Moreover, it not only produces this diffusion at the time of growth, but it may produce it by the annealing treatment after growth.
[0005] Furthermore, the result of having examined the memory effect by which Mg sticks to the quartz reactor which is the fission reactor of MOVPE growth equipment is indicated by "Journal of Crystal Growth and Vol.145 pp(1994).214-218." According to this paper, since Mg has a memory effect, even if it introduces a lot of Cp2 Mg for a short time into a fission reactor, Mg distribution in a GaN crystal does not become steep, but it is shown that delay arises with a dope.
[0006] It is known that in the case of the group III-V semiconducter who grows by the gallium-arsenide (GaAs) system on the other hand on the substrate which can carry out lattice matching diffusion of Mg can be controlled when concentration dopes Si which is n mold dopant about [1x1020cm -] to three at high concentration ("Journal of Crystal Growth, Vol.107 (1991) pp.779-783").
[0007] Moreover, according to JP,6-283825,A, in GaN system semi-conductor luminescence equipment, it is shown by by considering as the undoping layer which does not dope a part of p mold cladding layer which consists of a p mold AlGaN in p mold that diffusion of Mg to the barrier layer formed directly under p mold cladding layer can be controlled.
[0008]
[Problem(s) to be Solved by the Invention] However, since the substrate which carries out lattice matching to GaN does not exist, in case a GaN system semi-conductor manufactures an epitaxial substrate, it cannot but serve as heteroepitaxial growth using the grid mismatching substrate which consists of sapphire (crystal aluminum 2O3), silicon carbide (SiC), etc. Thereby, although the defect density under crystal is about 103 cm-2 with a GaAs system semi-conductor, there is a problem that defect density cannot acquire the p-n junction which p mold dopant is easily spread through this penetration rearrangement, and has a steep impurity profile since many penetration rearrangements arise extremely with about 109 cm-2, with a GaN system semi-conductor.
[0009] Moreover, the conventional semi-conductor luminescence equipment indicated by JP,6-283825,A has the problem that the series resistance of the p-n junction section increases since the AlGaN layer with a larger band gap than GaN is considered as undoping as a diffusion control layer, and the increment in series resistance promotes working generation of heat of luminescence equipment, and

reduces the dependability of luminescence equipment remarkably.
[0010] This invention solves said conventional problem and aims at enabling it to form the p-n junction which has a steep dopant profile in a gallium nitride system semi-conductor.
[0011]
[Means for Solving the Problem] In order to attain the aforementioned purpose, this invention is considered as the configuration which prepares the semi-conductor layer which comes to dope p mold dopant and n mold dopant to coincidence (KODOPU) in the field by the side of the n-type-semiconductor layer of the p type semiconductor layer in the p-n junction section which consists of a p type semiconductor layer and a n-type-semiconductor layer in a gallium nitride system semi-conductor.
[0012] The process which forms the 1st semi-conductor layer which consists of undoping or an n mold gallium nitride system semi-conductor on the substrate with which lattice matching of the manufacture approach of the semi-conductor concerning this invention is not carried out to a gallium nitride system semi-conductor, It has the process which forms the 2nd semi-conductor layer which consists of a gallium nitride system semi-conductor on the 1st semi-conductor layer while KODOPU [p mold dopant and n mold dopant], and the process which forms the 3rd semi-conductor layer which consists of a p mold gallium nitride system semi-conductor on the 2nd semi-conductor layer.
[0013] According to the manufacture approach of the semi-conductor of this invention, between the 3rd semi-conductor layer which consists of the 1st semi-conductor layer and p mold gallium nitride system semi-conductor which consist of undoping or an n mold gallium nitride system semi-conductor Since the 2nd p mold dopant and n mold dopant in a semi-conductor layer form a neutrality atomic pair electrically by the Coulomb interaction in order to form the 2nd semi-conductor layer [KODOPU / 2nd / p mold dopant and n mold dopant] It is hard coming to spread p mold dopant contained in the 3rd semi-conductor layer.
[0014] In the manufacture approach of the semi-conductor of this invention, it is desirable that the thickness of the 2nd semi-conductor layer is 5nm or more and 500nm or less.
[0015] It is desirable to have further the process at which the manufacture approach of the semi-conductor of this invention forms the 4th semi-conductor layer which absorbs a gallium atom on the 3rd semi-conductor layer, and the process which heat-treats to the 4th semi-conductor layer.
[0016] The 1st cladding layer which the 1st semiconductor device concerning this invention becomes from n mold gallium nitride system semi-conductor formed on the substrate by which lattice matching is not carried out to a gallium nitride system semi-conductor, The barrier layer which consists of a gallium nitride system semi-conductor formed on the 1st cladding layer, It was formed on the barrier layer and has the diffusion control layer which consists of a gallium nitride system semi-conductor [KODOPU / semi-conductor / p mold dopant and n mold dopant], and the 2nd cladding layer which consists of a p mold gallium nitride system semi-conductor formed on the diffusion control layer.
[0017] Since according to the 1st semiconductor device the diffusion control layer which comes KODOPU [p mold dopant and n mold dopant] is formed between the 2nd cladding layer which consists of a barrier layer and a p mold gallium nitride system semi-conductor and p mold dopant and n mold dopant in this diffusion control layer form a neutrality atomic pair electrically by the Coulomb interaction, it is hard coming to spread p mold dopant contained in the 2nd cladding layer in a barrier layer side.
[0018] The 1st cladding layer which the 2nd semiconductor device concerning this invention becomes from n mold gallium nitride system semi-conductor formed on the substrate by which lattice matching is not carried out to a gallium nitride system semi-conductor, It has the barrier layer which consists of a gallium nitride system semi-conductor formed on the 1st cladding layer, the diffusion control layer which consists of an n mold gallium nitride system semi-conductor formed on the barrier layer, and the 2nd cladding layer which consists of a p mold gallium nitride system semi-conductor formed on the diffusion control layer.
[0019] Since the diffusion control layer which consists of an n mold gallium nitride system semi-conductor is formed between the 2nd cladding layer which consists of a barrier layer and a p mold gallium nitride system semi-conductor according to the 2nd semiconductor device, If p mold dopant

contained in the 2nd cladding layer is spread even in a diffusion control layer, since p mold dopant and n mold dopant in this diffusion control layer will form a neutrality atomic pair electrically by the Coulomb interaction It is hard coming to spread p mold dopant contained in the 2nd cladding layer in a barrier layer side.

[0020] In the 1st or 2nd semiconductor device, it is desirable that the thickness of a diffusion control layer is below the diffusion length of an electron hole.

[0021] In the 1st or 2nd semiconductor device, it is desirable that the thickness of a diffusion control layer is 5nm or more and 500nm or less.

[0022] It is desirable to have further the contact layer which the 1st or 2nd semiconductor device becomes from p mold gallium nitride system semi-conductor formed on the 2nd cladding layer, and the gallium absorption layer which is formed in the top face of this contact layer, and absorbs a gallium atom.

[0023] In the 1st or 2nd semiconductor device, p mold dopant is magnesium and it is desirable that n mold dopant is silicon.

[0024] In the 1st or 2nd semiconductor device, it is desirable that a diffusion control layer consists of Alx Ga1-x N (however, referred to as 0< x<1.).

[0025]

[Embodiment of the Invention] (1st operation gestalt) It explains, referring to a drawing about the 1st operation gestalt concerning this invention.

[0026] Drawing 1 (a) shows the cross-section configuration of the semi-conductor luminescence equipment concerning the 1st operation gestalt of this invention, and drawing 1 (b) shows the cross-section configuration of the semi-conductor luminescence equipment for a comparison. First, the manufacture approach of the semi-conductor luminescence equipment shown in drawing 1 R> 1 (a) and (b) is explained. In drawing 1 (a) and (b), a substrate 10 is held on the susceptor which performed ultrasonic cleaning using an organic solvent to the substrate 10 which consists of sapphire (crystal aluminum 2O3) beforehand, then was prepared in the fission reactor of organic metal vapor growth (MOVPE) equipment (not shown). Next, after carrying out evacuation of the inside of a fission reactor, when a pressure heats a substrate 10 for 15 minutes at about 1100 degrees C in the hydrogen ambient atmosphere of 70Torr(s), heat cleaning on the front face of a substrate is performed.

[0027] Then, after lowering a fission reactor even at about 500 degrees C, a flow rate introduces into a fission reactor the hydrogen whose flow rate is carrier gas in a part for 2.5L/about the ammonia whose flow rate is a nitrogen source in a part for 2micro mol/about the trimethylgallium (TMG) which is a source of a gallium by part for 2L/, respectively, and the low-temperature buffer layer 11 which becomes the top face of a substrate 10 from GaN whose thickness is 30nm is grown up.

[0028] Next, after carrying out the temperature up of the fission reactor even to about 1000 degrees C, the silane gas (SiH4) containing Si which is n mold dopant is newly introduced into a fission reactor. Thickness grows up into the top face of the low-temperature buffer layer 11 n mold contact layer 12 which high impurity concentration becomes from the n mold GaN of 1x1018cm-3 by 3 micrometers. Then, the trimethylaluminum (TMA) which is a source of aluminum is newly introduced into a fission reactor. Thickness grows up into the top face of n mold contact layer 12 n mold cladding layer 13 which high impurity concentration becomes from n mold aluminum0.1 Ga0.9 N of 1x1018cm-3 by 0.3 micrometers. Then, the 1st lightguide layer 14 which consists installation of TMA of GaN whose thickness is 0.1 micrometers on the top face of a stop and n mold cladding layer 13 is grown up.

[0029] Next, after lowering a fission reactor at about 800 degrees C, the quantum well barrier layer 15 and thickness which make nitrogen carrier gas and consist of In0.20Ga0.80N whose thickness is 3nm carry out sequential growth of the 2nd lightguide layer 16 which consists of GaN which is 0.1 micrometers.

[0030] Next, carry out the temperature up of the fission reactor even to about 1000 degrees C again, and the high impurity concentration of Mg is set to 5x1019cm-3 in the Cp2 Mg gas containing Mg which is p mold dopant. And SiH4 containing Si which is n mold dopant Adding gas to material gas so that the high impurity concentration of Si may be set to 1x1020cm-3 The diffusion control layer 17 which

becomes the top face of the 2nd lightguide layer 16 from aluminum0.1 Ga0.9 N whose thickness is 20nm is grown up. Then, SiH4 Supply of gas is stopped and p mold cladding layer 18 which becomes the top face of the diffusion control layer 17 from p mold aluminum0.1 Ga0.9 N whose thickness is 0.28 micrometers is grown up. Here, in the case of the semi-conductor luminescence equipment shown in drawing 1 (b), since the diffusion control layer 17 is not formed, the thickness of p mold cladding layer 18 is set to 0.3 micrometers.

[0031] Next, for thickness, the high impurity concentration of Mg is p+ of 1x1020cm-3 at 0.4 micrometers to the top face of p mold cladding layer 18. Annealing treatment whose temperature is 700 degrees C and 1 hour in nitrogen-gas-atmosphere mind is performed to the epitaxial substrate which p mold contact layer 19 which consists of a mold GaN was grown up, then grew, and p mold cladding layer 18 and p mold contact layer 19 are formed into low resistance.

[0032] Next, dry etching is performed to some epitaxial substrates, n mold contact layer 12 is exposed, and while forming alternatively the n lateral electrode 20 which becomes this exposure from Ti/Au, the p lateral electrode 21 of a stripe configuration with which width of face consists of nickel/Au by 10 micrometers is formed in the top face of p mold contact layer 19. Moreover, dry etching is performed to n mold cladding layer 13, the 1st lightguide layer 14, the quantum well barrier layer 15, the 2nd lightguide layer 16, the diffusion control layer 17, p mold cladding layer 18, and p mold contact layer 19, and a resonator is formed.

[0033] Hereafter, the property of the semi-conductor luminescence equipment constituted as mentioned above is explained, referring to a drawing.

[0034] the semi-conductor luminescence equipment which drawing 2 (a) requires for this operation gestalt -- secondary ion mass analysis (SIMS) -- the dopant profile measured using law is shown and drawing 2 (b) shows the dopant profile of the semi-conductor luminescence equipment for a comparison. It turns out that Mg of p mold dopant was not spread in the lightguide layers 14 and 16 and the quantum well barrier layer 15 which are located while the depth from the top face of an epitaxial substrate is 0.7 micrometers - 0.9 micrometers, as shown in drawing 2 (a), but the steep dopant profile has been obtained to them, and the diffusion control layer 17 is working effectively. On the other hand, as shown in drawing 2 (b), in not forming the diffusion control layer 17, it turns out that Mg of p mold dopant is spread even to the field in which the lightguide layers 14 and 16 and the quantum well barrier layer 15 are formed.

[0035] Furthermore, before the annealing treatment which forms p mold cladding layer 18 and p mold contact layer 19 into low resistance, a spatter is used for the top face of p mold contact layer 19, and it consists of silicon oxide (SiO2) whose thickness is 80nm, and if annealing treatment is performed after making the gallium absorption layer which absorbs Ga atom deposit, a profile still steeper than the dopant profile shown in drawing 2 (a) can be obtained. This is SiO2. The becoming gallium absorption layer absorbs Ga atom during annealing treatment, and p mold contact layer 19 is made to produce many holes, and when Mg atom which is p mold dopant is ****(ed) by this hole, it is because it is hard coming to be spread in a barrier layer side.

[0036] Drawing 3 (a) expresses the emission spectrum reinforcement of the semi-conductor luminescence equipment concerning this operation gestalt, and drawing 3 (b) expresses the emission spectrum of the semi-conductor luminescence equipment for a comparison. Drawing 3 (a) is the case where poured in a 20mA direct current and it is operated at a room temperature to the semi-conductor luminescence equipment concerning this operation gestalt, and only the 420nm spectrum which is quantum level luminescence from the quantum well barrier layer 15 has appeared.

[0037] On the other hand, in the case of the semi-conductor luminescence equipment for a comparison shown in drawing 3 (b), the 420nm spectrum which is quantum level luminescence from the quantum well barrier layer 15, and the 450nm spectrum which is the level formed of diffusion of Mg overlapped, and it has appeared. In addition, if the direct current to pour in is made small with 2mA, a 450nm spectrum will become more remarkable. The poured-in carrier contributes to luminescence with the luminescence level by the side of the low energy whose wavelength is 450nm, and this originates in changing with the increment in an inrush current to the luminescence level by the side of the high energy

whose wavelength is 420nm. That is, when not forming the diffusion control layer 17, there will be much reactive current which does not contribute to quantum level luminescence of the quantum well barrier layer 15, and it will cause the fall of color purity, and decline in luminous efficiency.

[0038] Since it has the diffusion control layer 17 which controls the diffusion by the side of the barrier layer of p mold dopant in the case of the semi-conductor luminescence equipment concerning this operation gestalt and Mg which is p mold dopant cannot diffuse it easily in the quantum well barrier layer 15, it turns out that only the 420nm spectrum was observed from low current to 20mA, and the poured-in carrier has contributed effective in luminescence from quantum level.

[0039] Moreover, as a result of comparing each current-voltage characteristic of the semi-conductor luminescence equipment and the semi-conductor luminescence equipment for a comparison concerning this operation gestalt, the increment in the series resistance by having formed the diffusion control layer 17 was not seen, but indicated the about [5V] electrical potential difference to be also both luminescence equipment at the time of impregnation of 20mA of direct current. As for this, wavelength can obtain the purple-blue colored light which is 420nm, without meaning that the thickness of the diffusion control layer 17 is poured into a barrier layer side comparatively easily [the electron hole poured in in about 20nm], and causing the rise of a threshold electrical potential difference, if this thickness is 5nm - about 500nm and it is 10nm - about 80nm desirably.

[0040] As explained above, the semi-conductor luminescence equipment concerning this operation gestalt can raise color purity and luminous efficiency sharply, without making the series resistance of luminescence equipment increase, since it has the diffusion control layer 17 which controls the diffusion by the side of the barrier layer of Mg which is p mold dopant between the 2nd lightguide layer 16 and p mold cladding layer 18.

[0041] Moreover, since aluminum0.1 Ga0.9 N is used for the diffusion control layer 17, since the bonding strength of a crystal lattice is larger than GaN, AlGaN can control diffusion of Mg more effectively.

[0042] In addition, in this operation gestalt, although not only this but carbon (C), zinc (Zn), and beryllium (Be) could be used although magnesium (Mg) was used for p mold dopant, and silicon (Si) was used for n mold dopant, you may be oxygen (O).

[0043] Moreover, although sapphire (crystal aluminum 2O3) was used for the substrate, silicon carbide (SiC) may be used. In this case, since silicon carbide has conductivity, etching of the epitaxial substrate for forming the n lateral electrode 20 becomes unnecessary, and the n lateral electrode 20 can be formed in the p lateral electrode 21 of a substrate 10, and the field of the opposite side.

[0044] (2nd operation gestalt) It explains, referring to a drawing about the 2nd operation gestalt concerning this invention hereafter.

[0045] Drawing 4 shows the cross-section configuration of the semi-conductor luminescence equipment concerning the 2nd operation gestalt of this invention, and omits explanation by giving the same sign to the same configuration member as the configuration member shown in drawing 1 (a) in drawing 4 .

[0046] The description of this operation gestalt is considered as the configuration embedded at n mold cladding layer 13, without inserting the quantum well barrier layer 15 by the p-n junction which consists of an n mold cladding layer 13 and a p mold cladding layer 18.

[0047] First, the manufacture approach of the semi-conductor luminescence equipment shown in drawing 4 is explained. the 1st operation gestalt -- the same -- MOVPE -- after carrying out sequential growth of the low-temperature buffer layer 11 and the n mold contact layer 12 on the substrate 10 which consists of sapphire using law, thickness grows up into the top face of n mold contact layer 12 1st n mold cladding layer 13A which high impurity concentration becomes from n mold aluminum0.1 Ga0.9 N of 1x1018cm-3 by 0.28 micrometers.

[0048] Next, the 1st lightguide layer 14 which becomes the top face of 1st n mold cladding layer 13A from GaN whose thickness is 0.1 micrometers, the quantum well barrier layer 15 which consists of In0.20Ga0.80N whose thickness is 3nm, and thickness carry out sequential growth of the 2nd lightguide layer 16 which consists of GaN which is 0.1 micrometers. Then, it has the same presentation as 1st n mold cladding layer 13A on the top face of the 2nd lightguide layer 16, and 2nd n mold cladding layer

13B as a diffusion control layer whose thickness is 20nm is grown up.
[0049] Next, for thickness, the high impurity concentration of Mg is [p mold cladding layer 18 which becomes the top face of 2nd n mold cladding layer 13B from p mold aluminum0.1Ga0.9 N whose thickness is 0.3 micrometers, and] p+ of 1x1020cm-3 at 0.4 micrometers. Sequential growth of the p mold contact layer 19 which consists of a mold GaN is carried out. Then, after making the gallium absorption layer 22 which uses a spatter for the top face of p mold contact layer 19, and consists of silicon oxide whose thickness is 80nm deposit, annealing treatment is performed and p mold cladding layer 18 and p mold contact layer 19 are formed into low resistance.
[0050] Next, dry etching is performed to some epitaxial substrates, n mold contact layer 12 is exposed, and while forming alternatively the n lateral electrode 20 which becomes this exposure from Ti/Au, after removing the gallium absorption layer 22 alternatively, the p lateral electrode 21 of a stripe configuration with which width of face consists of nickel/Au by 10 micrometers is formed in the top face of p mold contact layer 19. Moreover, dry etching is performed to 1st n mold cladding layer 13A, the 1st lightguide layer 14, the quantum well barrier layer 15, the 2nd lightguide layer 16, n mold cladding layer 13of ** 2nd B, p mold cladding layer 18, and p mold contact layer 19, and a resonator is formed.
[0051] Thus, since 2nd n mold cladding layer 13B is already formed in the top face of the 2nd lightguide layer 16 in this operation gestalt at the time of growth of p mold cladding layer 18, and subsequent annealing treatment, While the distance from p mold cladding layer 18 to the quantum well barrier layer 15 becomes large In order that p mold dopant from p mold cladding layer 18 may form a neutrality atomic pair electrically by n mold dopant and the Coulomb interaction in 2nd n mold cladding layer 13B, the diffusion by the side of a barrier layer comes to be controlled more strongly.
[0052] Hereafter, the property of the semi-conductor luminescence equipment constituted as mentioned above is explained, referring to a drawing.
[0053] Drawing 5 shows the dopant profile which measured the semi-conductor luminescence equipment concerning this operation gestalt using the SIMS method. It turns out that Mg of p mold dopant is not spread in the active region which consists of the lightguide layers 14 and 16 and the quantum well barrier layer 15 which are located while the depth from the top face of an epitaxial substrate is 0.72 micrometers - 0.92 micrometers, as shown in drawing 5 , but the steep dopant profile is obtained in it, and 2nd n mold cladding layer 13B is working effectively as a diffusion control layer.
[0054] Furthermore, the semi-conductor luminescence equipment concerning this operation gestalt Also in impregnation of a direct current, from only the 420nm spectrum which is quantum level luminescence of the quantum well barrier layer 15 being observed from the time of low current impregnation Have contributed only to quantum level luminescence of the quantum well barrier layer 15 which the poured-in carrier becomes from InGaN, and it also sets to the current-voltage characteristic. The remarkable increment in the series resistance by having embedded the quantum well barrier layer 15 into n mold cladding layer [not the p-n junction section but] 13A and 13B was not checked, but when a direct current was 20mA, it showed the about [6V] electrical-potential-difference value. Here, the thickness of 2nd n mold cladding layer 13B can obtain the purple-blue colored light which is diffusion length extent of an electron hole and 5nm - about 500nm of whose wavelength is 420nm, without causing the rise of a threshold electrical potential difference if it is 10nm - 80nm desirably.
[0055] As explained above, in order that the semi-conductor luminescence equipment concerning this operation gestalt may control the diffusion from p mold cladding layer side to the barrier layer side of Mg which is p mold dopant by embedding an active region into n mold cladding layer, it can obtain a steep dopant profile easily and certainly, and color purity and its luminous efficiency improve sharply.
[0056] Moreover, since it has the gallium absorption layer 22 which absorbs Ga atom on the top face of p mold contact layer 19, when Mg is ****(ed) by the hole of Ga atom, the diffusion by the side of the barrier layer of Mg is controlled further.
[0057] Moreover, since 2nd n mold cladding layer 13B used as a diffusion control layer consists of aluminum0.1 Ga0.9 N, since the bonding strength of a crystal lattice is larger than GaN, AlGaN can control diffusion of Mg more effectively.

[0058] In addition, also in this operation gestalt, although not only this but carbon (C), zinc (Zn), and beryllium (Be) could be used although magnesium (Mg) was used for p mold dopant, and silicon (Si) was used for n mold dopant, you may be oxygen (O).
[0059] Moreover, although sapphire (crystal aluminum 2O3) was used for the substrate, silicon carbide (SiC) may be used.
[0060] Moreover, since the diffusion control approach of p mold dopant shown in the 1st and 2nd operation gestalten can perform easily interface control which was excellent in the p-n junction in a GaN system semi-conductor, it is applicable not only to luminescence equipment but other electron devices.
[0061]
[Effect of the Invention] In order that p mold dopant and n mold dopant may form a neutrality atomic pair electrically in the 2nd semi-conductor layer [KODOPU / 2nd / p mold dopant and n mold dopant] according to the manufacture approach of the semi-conductor concerning this invention, Since diffusion of p mold dopant contained in the 3rd semi-conductor layer is controlled, distribution of p mold dopant under crystal becomes steep, and when the 1st semi-conductor layer is n mold, the p-n junction excellent in interface control can be formed.
[0062] In the manufacture approach of the semi-conductor of this invention, the diffusion by the side of the 1st [of p mold dopant] semi-conductor layer can be controlled certainly, without increasing the series resistance value of the 1st semi-conductor layer and the 3rd semi-conductor layer as the thickness of the 2nd semi-conductor layer is 5nm or more and 500nm or less.
[0063] The process at which the manufacture approach of the semi-conductor of this invention forms the 4th semi-conductor layer which absorbs a gallium atom on the 3rd semi-conductor layer, Since p mold dopant is ****(ed) by the hole where the gallium atom of the 3rd semi-conductor layer was absorbed and formed in the 4th semi-conductor layer when it has further the process which heat-treats to the 4th semi-conductor layer, the diffusion by the side of the 1st [of p mold dopant] semi-conductor layer can be controlled further.
[0064] In order that this p mold dopant and this n mold dopant may form a neutrality atomic pair electrically in the diffusion control layer [KODOPU / layer / p mold dopant and n mold dopant] according to the 1st semiconductor device concerning this invention, Since diffusion of p mold dopant contained in the 2nd cladding layer is controlled, distribution of p mold dopant under crystal becomes steep, and the p-n junction the 1st cladding layer and 2nd cladding layer excelled [p-n junction] in interface control is formed.
[0065] According to the 2nd semiconductor device concerning this invention, it sets in the diffusion control layer of n mold. In order that p mold dopant from the 2nd cladding layer and n mold dopant in this diffusion control layer may form a neutrality atomic pair electrically and this diffusion control layer may control the diffusion by the side of the barrier layer of p mold dopant, Distribution of p mold dopant under crystal becomes steep, and the p-n junction the 1st cladding layer and 2nd cladding layer excelled [p-n junction] in interface control is formed.
[0066] In the 2nd semiconductor device, diffusion of p mold dopant can be controlled certainly, without barring impregnation of an electron hole as the thickness of a diffusion control layer is below the diffusion length of an electron hole.
[0067] In the 1st or 2nd semiconductor device, diffusion of p mold dopant can be controlled certainly, without barring impregnation of an electron hole as the thickness of a diffusion control layer is 5nm or more and 500nm or less (i.e., without a threshold electrical potential difference increasing).
[0068] The contact layer which the 1st or 2nd semiconductor device becomes from p mold gallium nitride system semi-conductor formed on the 2nd cladding layer, Since p mold dopant is ****(ed) by the hole where it was formed in the top face of this contact layer, and the gallium atom of the 2nd cladding layer was absorbed and formed in the gallium absorption layer when it had further the gallium absorption layer which absorbs a gallium atom, The diffusion by the side of the barrier layer of p mold dopant can be controlled further.
[0069] In the 1st or 2nd semiconductor device, p mold dopant is magnesium and the p-n junction which was excellent in interface control in the gallium nitride system semi-conductor in n mold dopant being

silicon can be formed certainly.

[0070] In the 1st or 2nd semiconductor device, if a diffusion control layer consists of Alx Ga1-x N (however, referred to as 0< x<1.), since the bonding strength of a crystal lattice is larger than GaN, Alx Ga1-x N can control diffusion of p mold dopant more effectively.

[Translation done.]